WKD SUPERLUMINAL EXPERIMENT EXPLAINED BY THE THEORY OF SUPERLUMINAL RELATIVITY*

Petar K. Anastasovski

Abstract

By using the concepts of the Theory of Superluminal Relativity, the explanation of WKD experiment is offered. The results of the analysis show that electron can travel, and electromagnetic waves can propagate in curved space-time between atoms, with faster than light speed in vacuum.

1. Introduction

According to the Einstein's Theory of Special Relativity (SR) the energy of the particle equivalent to its rest mass m_0, is [1], [2], [3]

$$E_0 = m_0 c^2 \tag{1}$$

where c is the speed of light vacuum.

The kinetic energy of the particle in motion with velocity v, is,

$$E_k = m_0 c^2 \left(\frac{1}{\sqrt{1 - \frac{\mathrm{v}^2}{c^2}}} - 1 \right) \tag{2}$$

Hence the total energy of the particle is,

$$E_t = E_0 + E_k = \frac{m_0 c^2}{\sqrt{1 - \frac{\mathrm{v}^2}{c^2}}} \tag{3}$$

or,

$$E_t = mc^2 \tag{4}$$

where,

$$m = \frac{m_0}{\sqrt{1 - \frac{\mathrm{v}^2}{c^2}}} \tag{5}$$

The latter equation shows that the mass of the particle is increased when the particle is accelerated.

According to the Theory of Superluminal Relativity (SLR), [4], particles can travel with faster than light speed, and frame of reference where that can happen correlate with the frame of reference where speed of light in vacuum is c. This will be shown at the end of the section.

* According to the Ref. [4], superluminal experiment is performed by L.J. Wang, A. Kuzmich and A. Dogariu

According to SLR the rest energy of the particle is the same with the rest energy in SR, that is, [†] [4],

$$E'_0 = E_0 = m_0 c^2 \tag{6}$$

The kinetic energy of the particle in SLR is, [3],

$$E'_k = m_0 c^2 \left(1 - \sqrt{1 - \frac{c^2}{\mathrm{v}^2}} \right) \tag{7}$$

where v > c.

The total energy of the particle in SLR is, [3],

$$E'_t = E'_0 - E'_k = m_0 c^2 \sqrt{1 - \frac{c^2}{\mathrm{v}^2}} \tag{8}$$

or,

$$E'_t = m' c^2$$

where,

$$m' = m_0 \sqrt{1 - \frac{c^2}{\mathrm{v}^2}} \tag{9}$$

The latter equation shows that in SLR the mass of the particle decreases when it is accelerated beyond the speed c, that is, for the velocities v > c. This has other big consequences, which will be shown later on.

The Eq. (3) shows that total energy of the particle in SR is equal to the rest mass plus the kinetic energy of the particle. The Eq. (8) shows, that total energy of the particle in SLR is equal to the rest mass minus the kinetic energy of the particle. Actually, the energy which in SLR is labelled as kinetic, is in fact, the energy, which is released by the particle during its motion with $c_s > c$. According to the basic concepts of quantum mechanics, this can happen as a result of particle transition from one energy state to another, in this case from the state with speed v to the state with speed c_s. The quantum of the released energy will be equivalent to the loss of the particles mass according to the Eq. (9). The result of this phenomenon is emission of new particle with mass equal to the loss of the mass of the initial particle, and with energy equivalent to that mass. For instance, nucleons in nuclear interactions may emit muons as binding particles. [4].

In the next section, an attempt to find out what kind of particles can be emitted from the electrons in the cesium cell of the WKD superluminal experiment, when they travel with speed $c_s > c$, will be presented.

[†] The SLR magnitudes are denoted by prime in order to be distinguished from those of SR.

2. The Basic Superluminal Phenomenon

According to the Ref. (5),(6): “In the experiment, the light pulse emerges on the far side of the atomic cell sooner if it had travelled through the same thickness in vacuum by a time difference that is 310 folds of the vacuum transit time”.

We shall assume that it means,

$$c_s = 310 \ \ c = 9.3 \cdot 10^{10} \, m/s \tag{10}$$

We shall also assume that in the cesium cell of the WKD superluminal experiment, there is an electron, which is travelling with speed c_s. The kinetic energy of this electron in SLR according to the Eq. (7) is,

$$E'_{ek} = m_{eo} c^2 \left(1 - \sqrt{1 - \frac{c^2}{c_s^2}} \right) \tag{11}$$

where,

$$m_{eo} = 9.108 \cdot 10^{-31} \, kg$$

is the rest mass of the electron. Hence the latter equation leads,

$$E'_{ek} = 4.3444 \cdot 10^{-19} \, J \tag{12}$$

The Eq. (6), determines the rest energy of the electron, which yields,

$$E'_{eo} = E_{eo} = 8.1972 \cdot 10^{-14} \, J \tag{13}$$

The total energy of the electron in SLR is defined by the Eq. (8), which yields,

$$E'_{et} = 8.19715 \cdot 10^{-14} \, J \tag{14}$$

Now we shall return to the kinetic energy of the electron, and what it means in SLR. As we have already stated before, the energy, which in SLR is labelled as “kinetic”, is in fact the energy, which is released by the particle moving with faster than light speed. In this case it will be applied for the electron moving with speed c_s.

Using the equation,

$$E'_{ek} = E_v = hv \tag{15}$$

we can determine the frequency which corresponds to this energy. Hence,

$$v = \frac{E'_{ek}}{h} \tag{16}$$

or,

$$v = 6.5626 \cdot 10^{14} \, Hz$$

There are two wavelengths, which correspond to this frequency: one in the SR and the other in SLR.

In the SR frame of reference, the wavelength is,

$$\lambda = \frac{c}{\nu} \tag{17}$$

or,

$$\lambda_b = 457.13 \, nm \tag{18}$$

which is in the blue region of the visible spectrum of light.

In the SLR frame of reference, the wavelength is,

$$\lambda_s = \frac{c_s}{\nu} \tag{19}$$

or,

$$\lambda_s = 1.417712 \cdot 10^5 \ nm \tag{20}$$

which is in the range of electromagnetic waves, known as medium radio frequencies.

The obtained results, which show that the same electron can emit photon with wavelength λ_b in SR and photon with λ_s in SLR, suggests the possibility for existence of phenomenon of anomalous dispersion. This will be explained in section 4.

3. Feynman Diagram of Superluminal Processes

The Feynman diagram will be used in this analysis as a very practical tool for representing interaction processes among the particles. Fig.1 shows Feynman diagram for the photon-electron interaction processes, which is assumed that are taking place in the cesium cell of the WKD superluminal experiment.

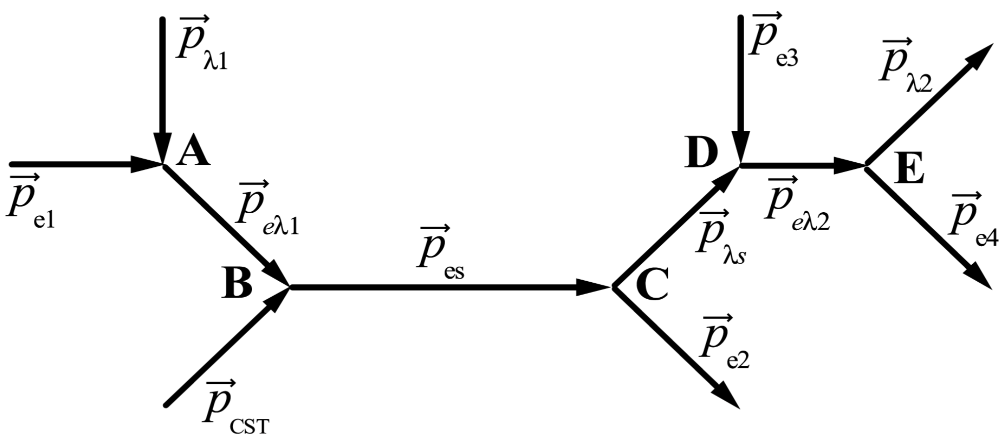

Fig. 1 The Feynman diagram presentation of superluminal processes in cesium cell.

Besides the photon-electron interactions, it will be assumed that main phenomenon which is taking place in cesium cell, is electron-cesium atom interactions. This interaction is assumed to be result of existence of curved space-time (CST) around nucleons and atoms. The presence of CST around cesium atoms will be expressed by the momentum $\vec{p}_{CST}$. The possibility for existence of CST around nucleons and atoms is predicted in the Ref. (4), and elaborated in the Ref. (7). The consequences of CST in electrodynamics are elaborated on in the Refs. (8-15). The most promising approach for determining the magnitude $\vec{p}_{CST}$ is the Sachs-Evans theory [12-15].

Vertex A

Interaction of the electron with momentum,

$$p_{e1} = m_{eo}\mathrm{v} \tag{21}$$

with photon with momentum,

$$p_{\lambda 1} = m_{\lambda 1}c \tag{22}$$

is taking place. The photon with mass,

$$m_{\lambda 1} = 4.827 \cdot 10^{-36}\ kg \tag{23}$$

has frequency,

$$\nu = 6.5626 \cdot 10^{14}\ Hz \tag{24}$$

and wavelength,

$$\lambda_1 = 457.13\ nm \tag{25}$$

This photon is in the blue region of the visible spectrum of the light.

According to the Quantum Mass Theory (QMT), [16], maximum photon-electron effect is achieved, if there is resonance between deBroglie wave of the electron and the wave of the incident light [17]. As a result of this interaction, the electron mass incorporate the photon mass. This interaction of the masses is given by the equation,

$$m_{e\lambda 1} = m_{eo} + \frac{1}{\alpha} m_{\lambda 1} \tag{26}$$

where,

$m_{e\lambda 1}$ – is the electron mass as a result of photon-electron interaction

m_{eo} – the mass of the electron before the interaction,

$m_{\lambda 1}$ – is photon's mass

$\alpha = \frac{e^2}{\hbar c} = 7.297 \cdot 10^{-3}$ - is the fine structure constant.

Since we do not know electron thermal and drift velocities in cesium cell, we shall take that the momentum of the electron before interaction is,

$$p_{e1} = m_{eo}\mathrm{v}$$

and after interaction is,

$$p_{e\lambda 1} = m_{e\lambda 1}\mathrm{v}_1 \tag{27}$$

Thus the resultant momentum of the electron after interaction with photon is,

$$p_{e\lambda 1} = p_{e1} + p_{\lambda 1} \tag{28}$$

Vertex B

At vertex B, electron with momentum $p_{e\lambda 1}$ interacts with momentum p_{CST}.

An important assumption is made here. It has already been mentioned that in Ref. [4], the possibility for existence of space-time curvature around nucleons and atoms is predicted, and is elaborated on in the Ref.(7). It is assumed that here in the electron-cesium atom interactions, distortion of the CST around atom is taking place. As a result of this CST distortion, the momentum p_{CST} is created, which is added to the electron momentum $p_{e\lambda 1}$. The resultant momentum of the electron, then will be,

$$p_{es} = p_{e\lambda 1} + p_{CST} \tag{29}$$

Hence, at the vertex B, the superluminal process is taking place. As a result of CST distortion, the electron will be in motion with faster than light speed in the CST between cesium atoms.

Vertex C

In the Section 2 of this paper, it was stated that an electron with c_s will emit photon with wavelength λ_s. That will happen at vertex C, where an energy transition of the electron will take place. Hence, the superluminal process, which will take place at vertex C, can be expressed by the equation,

$$p_{es} = p_{e2} + p_{\lambda s} \tag{30}$$

where,

$$p_{e2} = p_{e0} \tag{31}$$

$$p_{\lambda s} = m_{\lambda s} c_s \tag{32}$$

and, $m_{\lambda s}$ is the mass of the photon with wavelength λ_s.

Vertex D

Photon with momentum $p_{\lambda s}$ will interact with an electron, with momentum p_{e3}, and the electron with momentum,

$$p_{e\lambda 2} = p_{e3} + p_{\lambda s} \tag{33}$$

will emerge.

The momentum of the incident electron is,

$$p_{e3} = p_{e1} = m_{e0}\mathrm{v} \tag{34}$$

and the momentum of the emerged electron is,

$$p_{e\lambda 2} = m_{e\lambda 2}\mathrm{v} \tag{35}$$

where the mass of the emerged electron $m_{e\lambda 2}$ includes the mass of the photon, with wavelength

$$\lambda_2 = \lambda_1 = \lambda_b = 457.13\ nm \tag{36}$$

which is the wavelength of the incident light at vertex A.

Vertex E

At this vertex two possible processes may take place:

E-1

The electron with momentum $p_{e\lambda 2}$ will emit photon with wavelength

$$\lambda_2 = \lambda_1 = \lambda_b = 457.13\ nm \tag{37}$$

which is the wavelength of the incident light at the vertex A, and the residual part will be the electron with momentum,

$$p_{e4} = p_{e3} = p_{e1} = m_{e0}\,\mathrm{v} \tag{38}$$

which is the same with momentum of all incident electrons in the analysed process.

E-2

If at the point E the momentum p_{CST} is present again then the whole described process will be repeated until the photon with wavelength λ_b will enter the material of the cesium cell's wall. Hence, in the cesium cell the chain of the described interactions will take place. The photon with wavelength λ_b will leave the cell as a photon, which propagates with speed c.

4. Anomalous Dispersion

In the Refs. (5), (6) it is stated that the phenomenon which is responsible for superluminal propagation in cesium cell is, anomalous dispersion of light.

It is stated there that the dispersion between two closely-spaced gain lines is given by the expression,

$$\nu \frac{\mathrm{dn}}{\mathrm{d}\nu} < 0 \tag{39}$$

when group index is,

$$n_g = n + \nu \frac{dn}{d\nu} < 1 \tag{40}$$

where n is refractive index.

The group velocity is,

$$\mathrm{V}_g = \frac{c}{n_g} > c \tag{41}$$

This could be considered as a main magnitude in anomalous dispersion because it leads to the stated consequence: superluminal propagation.

The results presented in this section approve the assumption that anomalous dispersion is taking place in cesium cell. This is in accord with Refs. (5), (6), however differences in the general approaches for explanation of the observed superluminal phenomenon are substantial. According to Refs. (5), (6), the superluminal propagation is a result of anomalous dispersion.

We shall analyse the example presented in Refs. (5), (6).

The chosen frequency as an example is,

$$v = 3.5 \cdot 10^{14}\ Hz \tag{42}$$

The group index is,

$$n_g = -330\ (\pm 30) \tag{43}$$

and this is the last presented data of the given example. The Vg is not computed, which in fact leads to the main conclusion for propagation of the light in the cesium cell.

For this case, the Eq. (41) yields,

$$Vg = -\ 9.091 \cdot 10^{5}\ \text{m/s} \tag{44}$$

which means,

$$V_g < c \tag{45}$$

Consequence: no superluminal propagation‡.

Example 1

We shall compute n_g and V_g for the same frequency of the Refs. (5), (6), given by the Eq. (42) as Example 1. We shall use our method, and we shall compare the obtained data with those from the Refs. (5), (6).

The results of our analysis for the whole visible spectrum of the light are presented on the Fig.2, where,

n_s - is superluminal refractive index,

c_s - is the electron's superluminal speed, and,

λ_s - is the wavelength of the electromagnetic wave, which propagates with superluminal speed c_s.

The magnitudes n_s, c_s and λ_s are presented versus λ and v from the visible spectrum of light incident to cesium cell. We shall compute n_g and V_g for the same example of frequency,

$$v_2 = 3.5 \cdot 10^{14}\ Hz$$

but now using the concepts of our analysis.

According to the curve for n in the Fig.2, for this frequency is obtained,

$$n_{s2} = 2.408 \cdot 10^{-3} \tag{46}$$

and the next frequency will be,

$$v_1 = 3.75 \cdot 10^{14}\ Hz \tag{47}$$

with,

$$n_{s1} = 2.451 \cdot 10^{-3} \tag{48}$$

hence,

$$\Delta v = 0.25 \cdot 10^{14}\ Hz \tag{49}$$

and,

$$\Delta n = 4.3 \cdot 10^{-5} \tag{50}$$

‡ It should be assumed that something is missing in the Ref. [4], or merely there are some printing errors.

For group index Eq. (40) yields,

$$n_{gs} = 3.1 \cdot 10^{-3} \tag{51}$$

and for the group velocity by Eq. (41) is obtained,

$$V_{gs} = 9.677 \cdot 10^{10} \text{ m/s} \tag{52}$$

or,

$$V_{gs} = 322.5 \text{ c} \tag{53}$$

hence,

$$V_{gs} > \text{c} \tag{54}$$

Consequence: superluminal propagation.

Our computation confirms the assumption for superluminal propagation for the example, which is given in the Refs. (5), (6). It has to be pointed out that their computation was for two "closely-spaced gain lines" while here the computation was performed for two substantially different frequencies, which makes the result to be even more affirmative.

Example 2

We shall take two frequencies:

$$v_1 = 5.4545 \cdot 10^{14} \text{ Hz} \tag{55}$$

with refractive index,(according to Fig.2),

$$n_{s1} = 3.0 \cdot 10^{-3} \tag{56}$$

and frequency,

$$v_2 = 5.0 \cdot 10^{14} \text{ Hz} \tag{57}$$

with refractive index (according to Fig.2),

$$n_{s2} = 2.828 \cdot 10^{-3} \tag{58}$$

or,

$$\Delta n_s = 1.72 \cdot 10^{-4} \tag{59}$$

and,

$$\Delta v = 0.4545 \cdot 10^{14} \text{ Hz} \tag{60}$$

For the group index Eq (40) yields,

$$n_{gs} = 3.206 \cdot 10^{-3} \tag{61}$$

and by the Eq. (41) for group velocity is obtained,

$$V_{gs} = 9.35 \cdot 10^{10} \text{ m/s} \tag{62}$$

or,

$$V_{gs} = 311 \text{ c} \tag{63}$$

From the latter equation it is obvious that,

$$V_{gs} > \text{c} \tag{64}$$

Consequence: superluminal propagation.

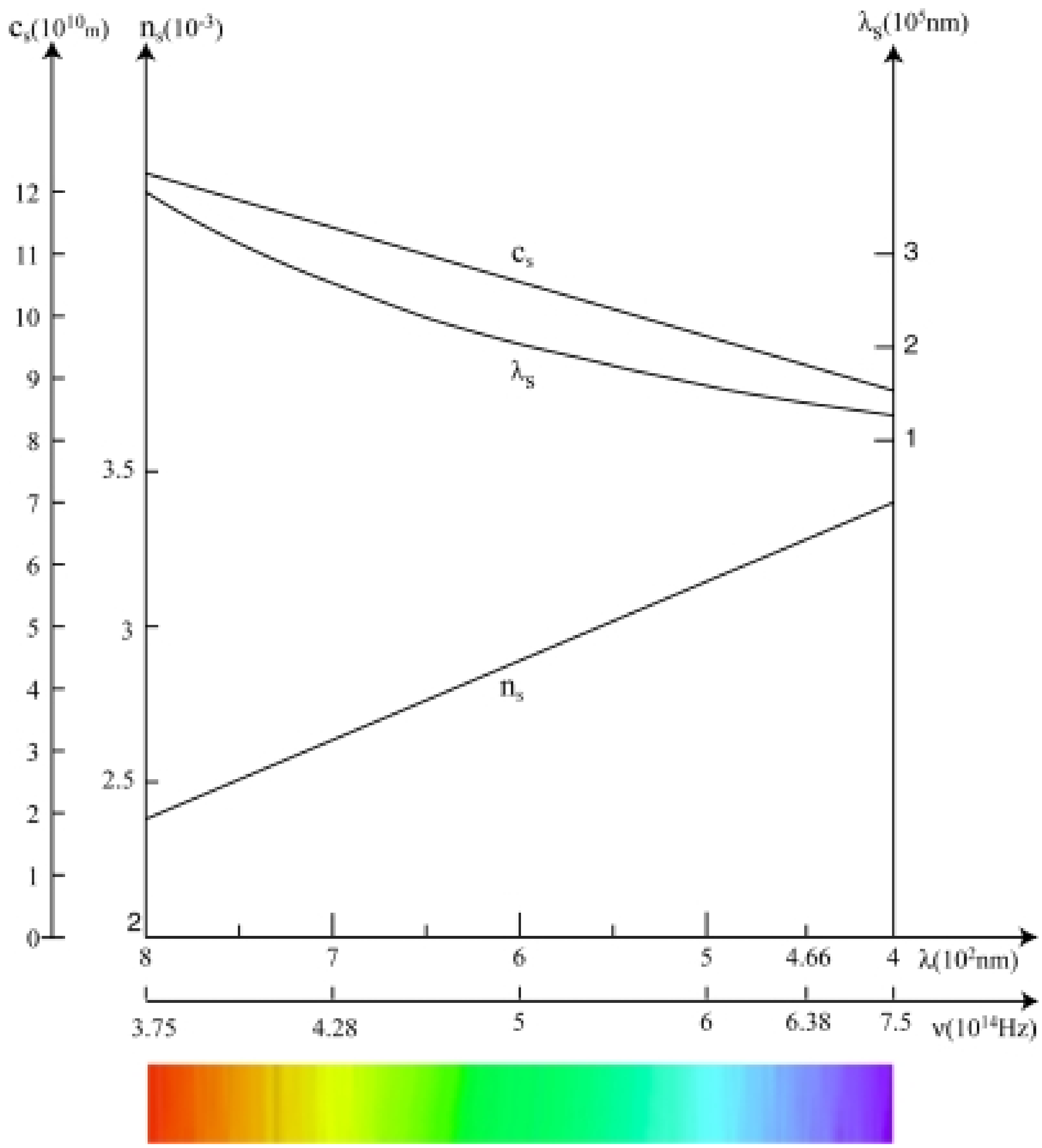

Fig. 2 Presentation of superluminal functions $c_s = f(\nu)$, $\lambda_s = f(\nu)$ and $n_s = f(\nu)$ where ν are the frequencies from the visible spectrum of light.

The values for V_{gs} obtained for two examples differ only 3.3%, which means that performed analysis is valid for the whole visible spectrum of light.

The mean value of group velocity $\overline{V}_{gs}$ for the whole visible spectrum of light is,

$$\overline{V}_{gs} = 9.65 \cdot 10^{10} \text{ m/s} \tag{65}$$

or,

$$\overline{V}_{gs} = 321.6 \text{ c} \tag{66}$$

It is necessary to quote once again Wang, Kuzmich and Dogariu: “It has been mistakenly reported that we have observed light pulse’s group velocity exceeding c by a factor of 300. This is erroneous. In the experiment the light pulse emerges on the far side of the atomic cell sooner that if it had travelled through the same thickness in vacuum by a time difference that is 310 folds of the vacuum transit time”. [5], [6]

The equation (66) shows that the result of the computation for $\overline{V}_{gs}$ is 3.7% different from “a time difference that is 310 folds of the vacuum transit time”. The results of the whole presented analysis seem to justify the assumption that V_{gs} is a group velocity in the observed superluminal experiment.

The mean value of computed superluminal speeds of the electrons, according to the curve on the Fig.2, is,

$$\overline{c}_s = 10.3 \cdot 10^{10} m/s \tag{67}$$

or,

$$\overline{c}_s = 343 \ c \tag{68}$$

The difference between V_{gs} and c_s is 6.7%. These two magnitudes V_{gs} and c_s have the same dimensions and same numerical superluminal values, but despite that, they express different phenomena. The first one V_{gs} determines propagation of electromagnetic waves, and the second one, c_s is superluminal speed of electrons in cesium cell. This means that, electrons moving with superluminal speed c_s make possible superluminal propagation of electromagnetic waves in cesium cell.

In this section we have applied WKD approach to explain the observed superluminal experiment. According to this approach, the basic phenomenon in cesium cell is anomalous dispersion and consequence is superluminal propagation of light. By using this approach, in fact we have confirmed that there is interconnection between anomalous dispersion and superluminal propagation of light in cesium cell, but not in this cause-consequence order, but vice-versa.

5. Conclusion

The results of the presented analysis based on the concepts of the theory of superluminal relativity, show that in the superluminal experiment performed by Wang, Kuzmich and Dogariu the main phenomenon is curved space-time distortion around cesium atoms, which produces superluminal processes, and the final effect is anomalous dispersion of light.

The final results of the analysis show that electron can travel, and electromagnetic waves can propagate in curved space-time between cesium atoms, with faster than light speed in vacuum, which has been observed in the WKD superluminal experiment.

References

1. Einstein, A.: Zur Elektrodynamik bewegter Körper, *Annalen der Physik*, **17**, 891, (1905).
2. Einstein A.: Ist die Trägheit eines Körpers von seinem Energiege halt abhängen? *Ann.d. Phys.* **18**, 639, (1905).
3. Anastasovski, P. K.: *Superluminal Relativity Related to Nuclear Forces and Structures,* U.S. Department of Energy website, http://www.ott.doe.gov/electromagnetic/papersbooks.html
4. Wang, L.J., Kuzmich, A. & Dogariu, A., Demonstraton Gain-Assisted Superluminal Light Propagation, http://www.neci.nj.nec.com/homepages/Lwan/demo.h
5. Anastasovski, P. K. & Benson, T. M., *Quantum Mass Theory Compatible with Quantum Field Theory*, Nova Science Publishers, Inc., New York, (1995).
6. Anastasovski, P. K., *Theory of Magnetic and Electric Susceptibilities for Optical Frequencies,* Nova Science Publishers, Inc., New York, (1990).
7. Anastasovski, P. K., & Hamilton, D. B., Space-Time Curvature Around Nucleons, U.S. Department of Energy website,

   http://www.ott.doe.gov/electromagnetic/papersbooks.html
8. Sachs, M., *Symmetry in Electrodynamics*, U.S. Department of Energy website,

   http://www.ott.doe.gov/electromagnetic/papersbooks.html
9. Lehnert, B. & Roy, S., *Extended Electromagnetic Theory*, (World Scientific, Singapore, 1998).
10. Evans, M.W., Crowell, L.B., *Classical and Quantum Electrodynamics and the B Field,* (World Scientific, Singapore, 2000).
11. Crowell, L. B., Generalized Heisenberg Uncertainty Principle for Quantum Fields in Curved Spacetime, *Found. Phis. Lett.,* **12**, 585 (1999).
12. Evans, M.W., et al., AIAS Group paper, Development of the Sachs Theory of Electrodynamics, *Optik,* 00-172, received 8th August (2000).
13. Evans, M.W., et al., AIAS Group paper, Electromagnetic Energy from Curved Space-Time, *Optik*, 00-156, received 25th June (2000).
14. Evans, M.W., et al., AIAS Group paper, Runaway Solutions of the Lehnert Equations: The possibility of extracting energy from the vacuum, *Optik*, received 18th March, accepted for publication, vol. **111** (2000).
15. Evans, M.W., et al., AIAS Group paper, Longitudinal Modes in Vacuo of the Electromagnetic Field in Riemannian Space-Time, *Optik*, awaiting acknowledgement of receipt.